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GROWTH TABLES FOR SELECTIVELY-CUT PONDEROSA PINE IN WESTERN MONTANA

by
Arthur L. Roe

- Northern -
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GROWTH TABLES FOR SELECTIVELY-CUT PONDEROSA PINE IN WESTERN MONTANA

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Arthur L. Roe 1/

INTRODUCTION

A study of cut-over ponderosa pine stands in western Montana was made in 1947 in answer to forest managers' requests for ways to predict growth of selectively-cut ponderosa pine timber. Growth responses to different intensities of cutting were analyzed on 60 half-acre temporary sample plots. Age of cutting varied from 5 to 50 years.

From the data obtained, a set of yield tables has been developed for predicting growth of residual trees after logging. The eight growth tables, and methods for their use, are the subject of this report. They are presented on pages 6 to 13. Two kinds of estimates can be made from these tables:

1. A general estimate of growth of residual stands on areas containing typical, or average, conditions, to be used principally for broad planning purposes.

2. A more precise prediction of the growth of residual stands which includes adjustments for stand competition, site index, and maturity.

HOW TO USE THE TABLES TO PREDICT BOARD-FOOT GROWTH IN CUT-OVER STANDS

GENERAL ESTIMATES

Growth may be estimated as an average figure which will be applicable to average or typical residual stands. Tables 1, 2, and 3 show average volume of residual trees by reserve stand classes up to 50 years after cutting by five-year intervals and site classes. The volumes given are net because mortality has been deducted. Table 1 represents growth estimates for typical or average site class conditions on cut-over areas

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1/ Division of Forest Management Research.

in western Montana. Tables 2 and 3 show values for site classes IV and V, respectively. To convert the values found in these tables to other site classes, use a 12-percent adjustment factor between site classes. For example, the values found in the site class IV tables when multiplied by 112 percent will be converted to corresponding values for site class III.

The board-foot volume of the reserve stand (trees 10 inches d.b.h. and larger at logging) and site class are the only stand statistics needed in order to use tables 1, 2, and 3. Site classification tables are presented in appendix tables 1 and 2. For example, assume that selective cutting in a ponderosa pine stand averaging site class IV left a reserve stand of 4500 board feet per acre and that the predicted volume of this stand in 30 years is required. The average volume of the residual stand 30 years later would be found as follows: (1) enter table 2 at the 4500 board-foot reserve stand class (interpolate between 4,000 and 5,000 board feet); (2) read the values in the 30-year column. The volume will be 6920 board feet 30 years after logging, representing a net growth of 2420 board feet (6920 bd. ft. - 4500 bd. ft.) in 30 years, or 80.7 board feet periodic annual growth. Ingrowth must be computed independently because it has not been included in these tables.

ADJUSTING GROWTH ESTIMATES FOR ADDITIONAL VARIABLES

To refine the growth prediction, greater knowledge is required concerning the reserve stand. The following information will be needed:

1. A stand table of the residual trees in the 1-inch d.b.h. class and larger.

2. Basal area of the reserve stand 9.6 inches d.b.h. and larger.

3. Site index (height in feet of the average dominant and codominant trees at 100 years). See appendix tables 1 and 2.

4. Age of residual trees - obtained by taking a weighted average of Keen age classes of sample residual trees.

After basal area has been derived from the stand table, summarize the survey data from the cut-over stand and compute growth as shown in the following example:

Reserve stand data:

1. Volume - 5000 board feet

2. Basal area - 50 square feet

3. Site index - 70 feet at 100 years (Site Class V)

4. Keen age - 2.6

5. Cutting cycle - 35 years

Growth compilation:

1. Derive gross growth by reading from table 4 for the correct basal area (50) and cutting cycle (35). In this instance, gross growth is 4850 board feet. Interpolate when values are intermediate to those shown in the table.

2. Obtain a correction factor (94 percent) for age (2.6) and site index (70) from table 5. This reduces growth to 4559 board feet (4850 X 0.94).

3. Take out mortality with the 15 percent average found in the study. 4559 - (.15 X 4559) or 4559 X 0.85 = 3875 board feet. This is net growth of the residual trees. In case the user of the table has at hand a more exact mortality correction factor for his particular stand, it should be used instead of the 15 percent average.

4. Sum the reserve stand volume and net growth to obtain net volume of the residual trees at the end of the cutting cycle or 5000 + 3875 = 8875 board feet per acre. Periodic annual growth is 3875/35 = 111 board feet.

5. Set up a stand table for determination of ingrowth, using field survey data as shown below:

D.B.H. class in inches	Trees per acre	
	Ponderosa pine (Number)	Douglas-fir (Number)
3	--	--
4	--	--
5	.19	2.75
6	--	2.17
7	.37	1.90
8	--	1.28
9	.92	.83
Total	1.48	8.93

6. Compute ingrowth from tables 6, 7, and 8 and the stand table prepared in step 5. Tables 6, 7, and 8 show the board-foot volume of pole size trees by five-year intervals after logging. In our problem, both ponderosa pine in site class V and Douglas-fir are present. Therefore, values for the solution are taken from table 7 for ponderosa pine and from table 8 for Douglas-fir. Values, read from the proper diameter class and five-year interval in the table, should be multiplied by the number of trees in the corresponding diameter class in the stand table. Thus, in the example there is 0.37 ponderosa pine tree per acre in the 7-inch d.b.h. class. A volume of 41 board feet is shown in table 7 for the volume of a 7-inch tree 35 years after logging. This volume multiplied by the number of trees per acre in the stand table will then give the volume per acre (41 X .37 = 15.17 bd. ft.). A tabulation like the following will be the result when volumes for the other diameter classes have been computed.

D.B.H. Class (Inches)	Ingrowth volume summary per acre	
	Ponderosa pine	Douglas-fir
	Bd. ft.	Bd. ft.
3	--	--
4	--	--
5	3/ 0.00	4/ 85.25
6	--	84.63
7	4/ 15.17	85.50
8	--	67.84
9	71.76	49.80
Total	86.93	373.02

3/ By referring to table 7, it will be seen that a five-inch ponderosa pine does not attain merchantable size in 35 years.
4/ Number of trees per acre times volume per tree.

The products derived are net values because average mortality has been deducted from pole volumes in the tables.

7. Obtain total volume of the stand 35 years after logging by summing the volume of residual trees and ingrowth. Computations follow:

Volume of residual trees at end of 35-year cutting cycle	8875	bd.	ft.
Ingrowth			
Ponderosa pine	87	"	"
Douglas-fir	373	"	"
Total predicted volume of stand 10" d.b.h. and larger at end of 35-year cutting cycle	9335	"	"
Periodic annual growth $\frac{3875 \text{ bd. ft.} + 87 \text{ bd. ft.} + 373 \text{ bd. ft.}}{35}$ =	124	"	"

LIMITATIONS ON USE OF TABLES

Two limitations of which the user should be aware apply to prediction of growth from these tables. One limitation pertains to species composition of stands. The stands studied contained, on the average, 77 percent ponderosa pine and 23 percent Douglas-fir by basal area. Hence, these tables should be used only for predicting growth of stands which are predominantly ponderosa pine. The other limitation applies to predicting growth in stands which have been cut two or more times. Growth estimates from the tables should not be applied directly unless growth in a cut-over stand has dropped back to about the pre-logging rate. If a stand is still benefiting from the stimulating effect of thinning caused by a previous logging, its initial growth rate at the time of the second cutting will be higher than the initial rate given in the growth tables. Therefore, the tables will generally underestimate growth after a second cutting. By adjusting for the higher initial growth at the time of second or later cuttings, the tables would be improved but the degree of improvement and the reliability of estimates would be unknown. The growth values in tables 1, 2, 3, and 4 should not be extended in order to permit prediction of growth in stands more heavily stocked than shown in the tables. It is probable that growth in more heavily stocked stands is influenced by stand density.

Table 1.--Volume per acre, Scribner rule, of ponderosa pine 1/ following selective cutting, by board-foot reserve stand classes, average site 2/, average stand structure

Volume at time of cutting	Volume after an interval of:									
	5 yrs.	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.	40 yrs.	45 yrs.	50 yrs.
Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.
1,000	3/ 1120	1290	1460	1650	1820	2020	2210	2400	2590	2770
2,000	2170	2400	2640	2890	3130	3380	3620	3860	4100	4330
3,000	3230	3520	3820	4140	4440	4740	5030	5320	5610	5890
4,000	4290	4640	4990	5380	5750	6100	6440	6780	7120	7440
5,000	5340	5750	6170	6620	7060	7460	7860	8240	8630	9000
6,000	6400	6870	7350	7870	8360	8820	9270	9700	10140	10550
7,000	7460	8000	8530	9120	9670	10140	10680	11160	11640	12110
8,000	8510	9100	9710	10360	10980	11540	12100	12620	13150	13660
9,000	9570	10220	10880	11600	12290	12900	13510	14090	14660	15220
10,000	10630	11340	12060	12850	13600	14260	14920	15540	16170	16780

1/ All trees 9.6 inches d.b.h. and larger are included.
2/ Average site index of basic data was 71 feet at 100 years, ranging from as low as 52 feet to as high as 92 feet.
3/ These are net values of growth obtained on residual trees only. Ingrowth is not included.

Basis: 60 one-half acre plots.

Table 2.--Volume per acre, Scribner rule, of ponderosa pine 1/ following selective cutting, by board-foot reserve stand classes, Site IV, average stand structure

Volume at time of cutting	Volume after an interval of:									
	5 yrs.	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.	40 yrs.	45 yrs.	50 yrs.
Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.
1,000 2/	1120	1300	1490	1690	1870	2080	2280	2490	2690	2890
2,000	2180	2430	2680	2950	3200	3460	3720	3980	4230	4480
3,000	3240	3550	3870	4210	4530	4850	5160	5470	5770	6070
4,000	4300	4680	5060	5470	5860	6230	6600	6960	7320	7660
5,000	5360	5800	6250	6730	7180	7610	8040	8450	8860	9250
6,000	6420	6920	7440	7990	8510	9000	9480	9940	10400	10840
7,000	7480	8050	8620	9250	9840	10340	10920	11430	11940	12430
8,000	8540	9170	9810	10510	11170	11770	12360	12920	13480	14020
9,000	9600	10300	11000	11770	12500	13150	13790	14410	15020	15610
10,000	10660	11420	12190	13030	13820	14530	15230	15890	16560	17200

1/ All trees 9.6 inches d.b.h. and larger are included.
2/ These are net values of growth obtained on residual trees only. Ingrowth is not included.

Basis: 60 one-half acre plots.

Table 3.--Volume per acre, Scribner rule, of ponderosa pine [1/] following selective cutting, by board-foot reserve stand classes, Site V, average stand structure

Volume at time of cutting	Volume after an interval of:									
	5 yrs.	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.	40 yrs.	45 yrs.	50 yrs.
Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.
1,000	[2/] 1110	1270	1430	1610	1780	1960	2140	2330	2510	2680
2,000	2160	2380	2600	2840	3070	3300	3530	3760	3990	4200
3,000	3220	3490	3770	4070	4360	4640	4920	5200	5470	5730
4,000	4270	4600	4940	5300	5650	5990	6310	6630	6950	7260
5,000	5320	5710	6110	6540	6940	7330	7700	8070	8430	8780
6,000	6380	6820	7280	7770	8240	8670	9110	9500	9910	10310
7,000	7430	7930	8450	9000	9530	9970	10480	10940	11390	11830
8,000	8480	9040	9610	10230	10820	11350	11880	12380	12870	13360
9,000	9540	10160	10780	11460	12110	12690	13270	13810	14360	14880
10,000	10590	11270	11950	12690	13400	14040	14660	15250	15840	16410

1/ All trees 9.6 inches d.b.h. and larger are included.
2/ These are net values of growth obtained on residual trees only. Ingrowth is not included.

Basis: 60 one-half acre plots.

Table 4.--Gross board-foot volume growth per acre of ponderosa pine residual trees, Scribner rule, following selective cutting 1/, by basal area reserve stand classes 2/, average site quality and age

Basal area of reserve stand at time of cutting	Volume after an interval of:									
	5 yrs.	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.	40 yrs.	45 yrs.	50 yrs.
Sq. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd.ft.	Bd. ft.	Bd. ft.
10 3/	130	330	520	740	940	1160	1380	1610	1820	2030
15	190	450	710	990	1260	1540	1810	2090	2360	2620
20	250	570	900	1250	1590	1920	2250	2570	2890	3200
25	310	690	1090	1510	1910	2300	2680	3060	3430	3780
30	370	820	1270	1760	2230	2680	3120	3540	3960	4370
35	430	940	1460	2020	2560	3060	3550	4020	4490	4950
40	490	1060	1650	2280	2880	3440	3980	4510	5030	5540
45	550	1180	1830	2540	3200	3820	4420	4990	5560	6120
50	610	1310	2020	2790	3530	4200	4850	5470	6100	6700
55	670	1430	2210	3050	3850	4570	5280	5960	6630	7290
60	730	1550	2400	3310	4170	4950	5720	6440	7170	7870

1/ All trees 9.6 inches d.b.h. and larger are included.
2/ Basal area is computed on trees 9.6 inches d.b.h. and larger in the reserve stand.
3/ To correct the values in this table for mortality, reduce by 15 percent or multiply by the conversion factor 85 percent.

Basis: 60 one-half acre plots.

Table 5.--Adjustment factors for effect of age and site quality upon board-foot volume growth of ponderosa pine following selective cutting

Average age (Keen class)	Average site index				
	50	60	70	80	90
	Percent	Percent	Percent	Percent	Percent
1.0	125	133	142	150	158
1.1	122	130	138	147	155
1.2	118	127	136	144	152
1.3	116	124	133	141	149
1.4	112	121	130	138	146
1.5	110	118	127	135	143
1.6	106	115	124	132	140
1.7	104	112	120	129	137
1.8	100	109	118	126	134
1.9	98	106	114	123	131
2.0	95	103	112	120	128
2.1	92	100	108	117	125
2.2	89	97	105	114	122
2.3	86	94	102	111	119
2.4	83	91	100	108	116
2.5	80	88	97	105	113
2.6	77	85	94	102	110
2.7	74	82	90	99	107
2.8	70	79	87	96	104
2.9	68	76	84	93	101
3.0	65	73	81	90	97
3.1	62	70	78	87	95
3.2	59	67	75	84	92
3.3	56	64	72	81	89
3.4	53	61	69	78	86
3.5	50	58	66	75	83
3.6	47	55	63	72	80
3.7	44	52	60	69	77
3.8	41	49	57	66	74
3.9	38	46	54	63	71
4.0	35	43	51	60	68

Table 6.--Volume 1/, Scribner rule, of pole-size ponderosa pine trees following selective cutting by d.b.h. classes, site quality IV (Site index 78)

D.B.H. class at time of cutting (Inches)	Volume per tree after an interval of:									
	5 yrs.	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.	40 yrs.	45 yrs.	50 yrs.
	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.
3	--	--	--	--	--	--	--	--	2/ 28	31
4	--	--	--	--	--	--	27	32	40	45
5	--	--	--	--	--	28	40	46	55	59
6	--	--	--	--	31	45	57	64	72	77
7	--	--	--	37	50	63	74	83	92	96
8	--	27	37	53	68	81	94	104	115	124
9	27	41	56	70	89	104	118	134	144	154

1/ Volumes are given for trees 9.6 inches d.b.h. and larger.
2/ Volumes in this table have been reduced by 5 percent to account for average mortality.

Table 7.--Volume 1/, Scribner rule, of pole-size ponderosa pine trees following selective cutting by d.b.h. classes, site quality V (Site index 64)

D.B.H. class at time of cutting (Inches)	Volume per tree after an interval of:									
	5 yrs.	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.	40 yrs.	45 yrs.	50 yrs.
	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.
4	--	--	--	--	--	--	--	--	--	2/ 21
5	--	--	--	--	--	--	--	19	26	30
6	--	--	--	--	--	19	26	32	38	42
7	--	--	--	19	27	34	41	48	52	56
8	--	--	24	33	42	50	58	64	67	71
9	18	37	39	49	58	69	78	82	86	93

1/ Volumes are given for trees 9.6 inches d.b.h. and larger.
2/ Volumes in this table have been reduced by 5 percent to account for average mortality.

Table 8.--Volume 1/, Scribner Rule, of pole-size Douglas-fir trees following selective cutting in ponderosa pine stands, by d.b.h. classes, site qualities IV and V

D.B.H. class at time of cutting (Inches)	Volume per tree after an interval of:									
	5 yrs.	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.	40 yrs.	45 yrs.	50 yrs.
	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.
1	--	--	--	--	--	--	--	--	--	2/ 25
2	--	--	--	--	--	--	--	--	28	32
3	--	--	--	--	--	--	--	27	33	39
4	--	--	--	--	--	--	25	32	40	45
5	--	--	--	--	--	27	31	39	47	50
6	--	--	--	--	25	32	39	45	52	57
7	--	--	--	27	32	40	45	50	59	64
8	--	--	27	34	41	48	53	58	65	70
9	21	28	35	43	48	55	60	65	71	76

1/ Volumes are given for trees 9.6 inches d.b.h. and larger.
2/ Volumes in this table have been reduced by 5 percent to account for average mortality.

APPENDIX TABLES

Appendix table 1.--Height of dominant and codominant trees of average breast-height diameter [1/]

Age (years)	Height, by site index--												
	40	50	60	70	80	90	100	110	120	130	140	150	160
	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
20	6	9	12	16	20	25	30	35	40	45	50	55	60
30	11	15	20	26	32	38	44	51	57	64	70	77	84
40	16	22	28	35	42	49	55	63	70	77	85	93	100
50	21	28	35	43	51	58	65	73	80	89	97	105	113
60	26	34	42	50	58	66	73	81	90	99	107	115	124
70	30	39	47	56	64	73	80	89	98	108	116	125	134
80	34	43	52	61	70	79	88	97	106	116	124	133	143
90	37	47	57	66	75	85	94	104	113	123	132	142	152
100	40	50	60	70	80	90	100	110	120	130	140	150	160
110	42	53	63	74	84	95	106	116	127	137	147	158	168
120	44	55	66	77	88	100	111	122	133	144	154	165	175
130	45	57	69	80	92	104	116	128	139	151	161	172	182
140	46	59	71	83	96	108	121	133	145	157	167	179	189
150	47	60	73	86	99	112	125	138	151	163	173	185	195
160	48	61	75	89	102	116	129	143	156	169	179	191	201
170	48	62	77	91	105	119	133	147	161	174	184	196	206
180	49	63	78	93	108	122	136	151	165	179	189	201	211
190	49	63	79	95	110	125	139	154	169	183	194	205	216
200	50	64	80	97	112	128	143	157	172	187	198	209	220

1/ Meyer, W. H., "Yield of even-aged stands of ponderosa pine." U. S. Dept. of Agr. Tech. Bul. 630, 60 pp., illus. 1938.

Appendix table 2.--Site-quality classification for ponderosa pine, with corresponding heights at maturity in terms of logs. 1/

Site quality class	Site index at 100 years		Logs in dominant trees at maturity 2/
	Central value	Range	
	Feet	Feet	Number
I	120	+113	10 or more
II	106	99--112	8 to 9
III	92	85--98	7
IV	78	71--84	5 to 6
V	64	57--70	3 to 4
VI	50	43--56	2.
VII	36	43-	2-

1/ Meyer, W. H., "Yield of even-aged stands of ponderosa pine." U. S. Dept. of Agr. Tech. Bul. 630, 60 pp., illus. 1938.

2/ Estimated in terms of 16-foot logs to 8-inch top. Maturity is assumed to begin at the age of 250 years.

LIST OF PREVIOUS PUBLICATIONS IN THIS SERIES

Station Paper No.	
1	*A preliminary study of root diseases in western white pine, by John Ehrlich. Oct. 1939.
2	*Possibilities of partial cutting in young western white pine, by E. F. Rapraeger. Jan. 1940.
3	*Blister rust control in the management of western white pine, by Kenneth P. Davis and Virgil D. Moss. June 1940.
4	Possibilities of wood-pulp production in the northern Rocky Mountain region, by E. F. Rapraeger. Mar. 1941.
5	Results to date of studies of the durability of native woods treated and untreated, by C. N. Whitney. Rev. Jan. 1946.
6	Changes in Benewah County forest statistics, by Paul D. Kemp. July 1947.
7	*A guide for range reseeding on and near the national forests of Montana, by C. Allan Friedrich. Oct. 1947.
8	*Pole blight - a new disease of western white pine, by C. A. Wellner. Nov. 1947.
9	Management practices for Christmas tree production, by C. A. Wellner and A. L. Roe. Nov. 1947.
10	The merits of lodgepole pine poles, by I. V. Anderson. Nov. 1947.
11	Tables for approximating volume growth of individual trees, by P. D. Kemp and M. E. Metcalf. Mar. 1948.
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